Brighton & Hove City Council

The countryside charity Sussex

Tree Inventory Report

Treeconomics

i-Tree

PREPARED BY:

John Rose - Treeconomics
Harry Munt - Treeconomics

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Contents

Executive Summary

This report highlights the findings of a study to record the structure and composition of the publicly owned trees within Brighton & Hove, to calculate some of their functions (benefits, public goods or eco-system services) and to value the services provided by those functions.

The city's public trees number some 36,800 with a replacement cost of £22.5m and a CAVAT amenity valuation of £549 million. They store approximately 14,900 tonnes of carbon, sequestering a further 425 tonnes every year. They also filter around 6.4 tonnes of air pollutants every year. Furthermore, they divert 15,300 cubic metres of rainwater from the drainage system whilst providing vital cooling to the urban streets.

Brighton & Hove displays a range of species, numbering some 164. The city is home to a substantial collection of Elm's which are celebrated due to the commitment of protecting the now rare and nationally significant population. Despite the healthy nature and intra-genus diversity of the Elm collection, this report highlights how Elms are above the recommended share of species and may leave the area vulnerable to certain threats. Notable genera performing well within the city in dealing with air pollution include Beech, Horse Chestnut and Plane.

The trees of Brighton & Hove bring a dynamic aspect to the otherwise hard landscape, providing a range of benefits that include flood protection, cleaner air and a more stable local microclimate. In the woodlands and rural areas, these benefits extend further to giving shape to the green recreational space and habitat for wildlife. These are benefits go well beyond a core ability to sequester carbon and produce oxygen.

However, in most landscapes these benefits provided by such 'natural capital' are often poorly understood, and frequently undervalued. Economic valuation of our natural capital can help to ensure appropriate funding and protection for this vital resource as society meets the twin challenges of climate change and biodiversity loss.
In order to produce values for some of the benefits provided by trees a state of the art, peer reviewed software system called i-Tree Eco[1] (referred to as 'Eco' throughout the report) was used.

[1] i-Tree is a suite of open source, peer-reviewed and continuously improved software tools developed by the USDA Forest Service and collaborators to help urban foresters and planners assess and manage urban tree populations and the benefits they can provide. i-Tree Eco is one of the tools in the i-Tree suite. It is designed to use complete or sample plot inventories from a study area along with other local environmental data to:

- Characterise the structure of the tree population;
- Quantify some of the environmental functions it performs in relation to air quality improvement, carbon dioxide reduction, and stormwater control;
- Assess the value of the annual benefits derived from these functions as well as the estimated worth of each tree as it exists in the
  landscape.
  i-Tree Eco is adaptable to multiple scales from a single tree to area-wide assessments. For more information see www.itreetools.org.

Tree Inventory - Headline Figures		
Total Number of Trees Measured	36,805	
Most Common Genus	*Ulmus (27.9%), Acer (14%), Prunus (5.8%)*	
Replacement Cost	£22.5 million	
CAVAT Valuation	£549 million	
Species Recorded	164	
Amounts and Values		
Carbon Storage	14,900 tonnes	£13.6 million
Pollution Removal	6.4 tonnes/yr	£101,000
Carbon Sequestration	425 tonnes/yr	£386,000
Avoided Runoff	15,300 m^3/yr	£27,500
Total Annual Benefits	**£514,500**	

Table 1: Headline Figures

Total Number of Trees Measured: Not all records supplied were used in the analysis.

Replacement Cost: value based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree) using the Council of Tree and Landscape Appraisers Methodology guidance from the Royal Institute of Chartered Surveyors

Carbon storage: the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation.

Carbon sequestration: the annual removal of carbon dioxide from the air by plants. Carbon storage and carbon sequestration values are calculated based on DBEIS[2] figures of £248 per metric ton of CO_2e for 2022.

Pollution removal: This value is calculated based on the UK social damage costs and the US externality prices where UK figures are not available; £956.63 per tonne (carbon monoxide), £8,433.49 per tonne (ozone), £11,973 per tonne (nitrogen dioxide), £6,925.90 per tonne (sulphur dioxide), £224,525 per tonne (particulate matter less than 2.5 microns).

Avoided Runoff: Based on the amount of water held in the tree canopy and re-evaporated after the rainfall event. The value is based on an average volumetric charge of £1.80 per cubic metre and includes the cost of avoided energy and associated greenhouse gas emissions.

Data processed using iTree Eco Version 6.0.29.

[2] DBEIS 2022

1. Introduction

1.1 Background Context

In the UK, both natural and managed habitats are under pressure. Whilst there is growing recognition of the role that urban green space has to play within dealing with the challenges of climate change and biodiversity loss, there is a long way to go.

There is a clear focus from government to create mechanisms to place a value on natural assets, as witnessed by the drive towards the concept of Natural Capital and Biodiversity Net Gain. A part of their role is to enable those charged with creating and managing our urban environment to balance the costs and benefits of their core activities against the impacts on our natural assets. That is, they are decision making tools.

The continued economic pressures as the country emerges from the early response to the pandemic, twinned with an ever growing population, means no let up on the natural environment. Every penny spent has to count and decisions are expected to be more frequently based on cost benefit analysis rather than purely on environmental grounds.

As many of the benefits provided by natural capital are not marketable, they are generally undervalued. This may lead to the wrong decisions being made about the natural environment.

Many recent Government documents have highlighted the importance of the range of benefits delivered by healthy functioning natural systems:

- The government's environment plan: 'A Green Future: Our 25 Year Plan to Improve the Environment[3]' recognises that the natural world 'underpins our nation's prosperity and wellbeing' and that in 'recent years we have come to realise that the environment does indeed deliver calculable economic benefits'.
- Our Vision for a Resilient Urban Forest[4] (2016) stresses the importance of recognising and investing in urban trees on account of the many benefits they provide to society.
- The Natural Capital Committee's third State of Natural Capital[5] (2015) urges government to better protect our natural capital and recommends that corporations begin to take account of these natural assets.
- UK National Ecosystem Assessment[6] (2011), highlighted that a healthy, properly functioning natural environment is the foundation of sustained growth, bringing benefits to communities and businesses.

[3] Defra, 2018

[4] UFWACN, 2016

[5] NCC, 2015

[6] UK NEA, 2011

1.2 Brighton and Hove Overview

Brighton and Hove has green space throughout. Higher populations of trees can be seen in wards with larger and more significant green space; the most prominent example of this is Westdene & Hove Park with 16.6% of the total number of trees, and which is home to Three Cornered Copse, Hove Park itself, and a large amount of common land to the North. The second and third highest number of trees are found in Coldean & Stanmer and Preston Park with 14.3% and 7.7% respectively. The ward with the lowest number of trees is Kemptown with 0.6%.

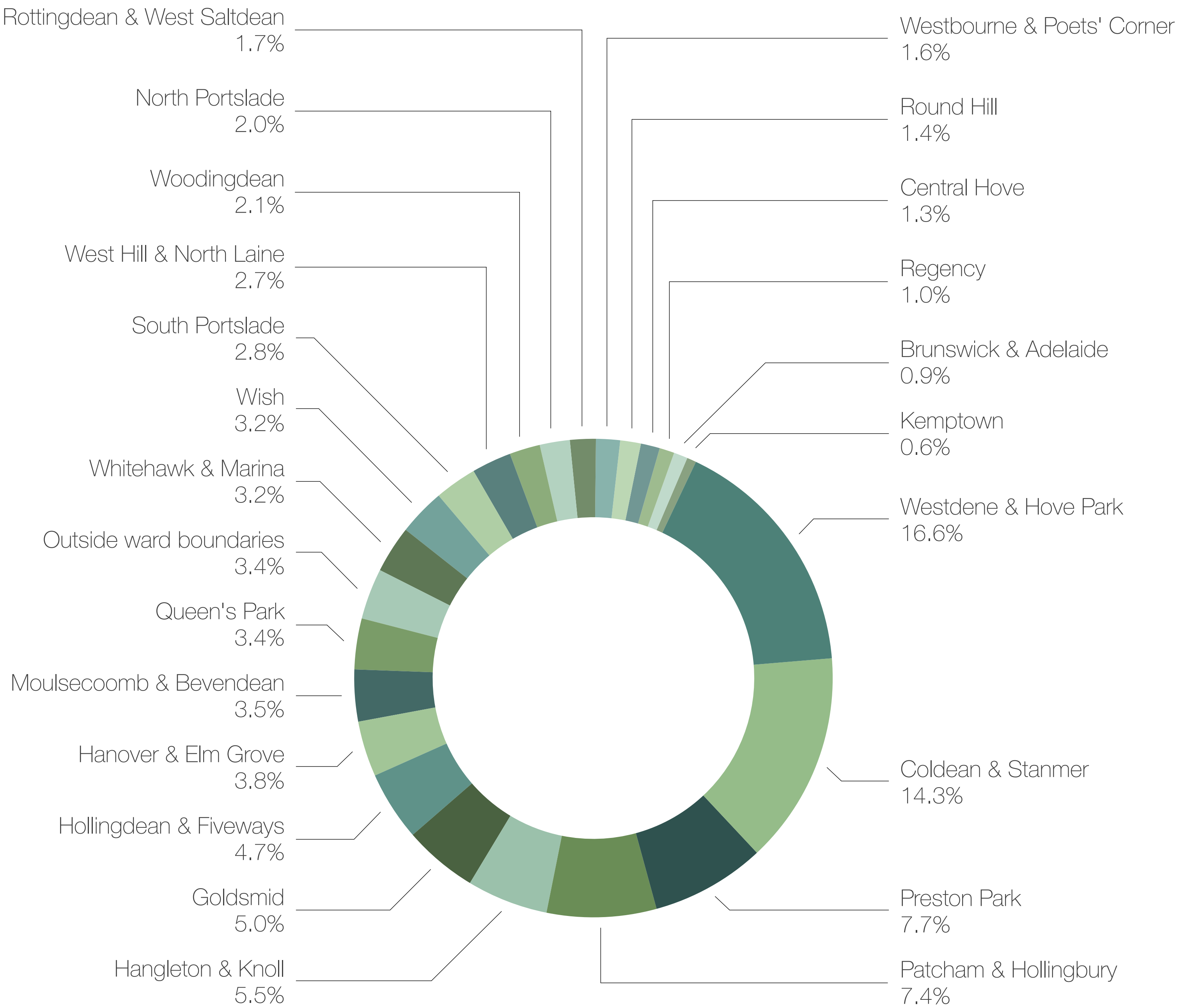

Figure 1: Tree population by ward

2. Urban Forest Characteristics

2.1 Tree Diversity

27.9% of the 36,805 trees in the inventory are *Ulmus*. The second and third most common trees are *Acer* with 14% and *Prunus* with 5.8%.

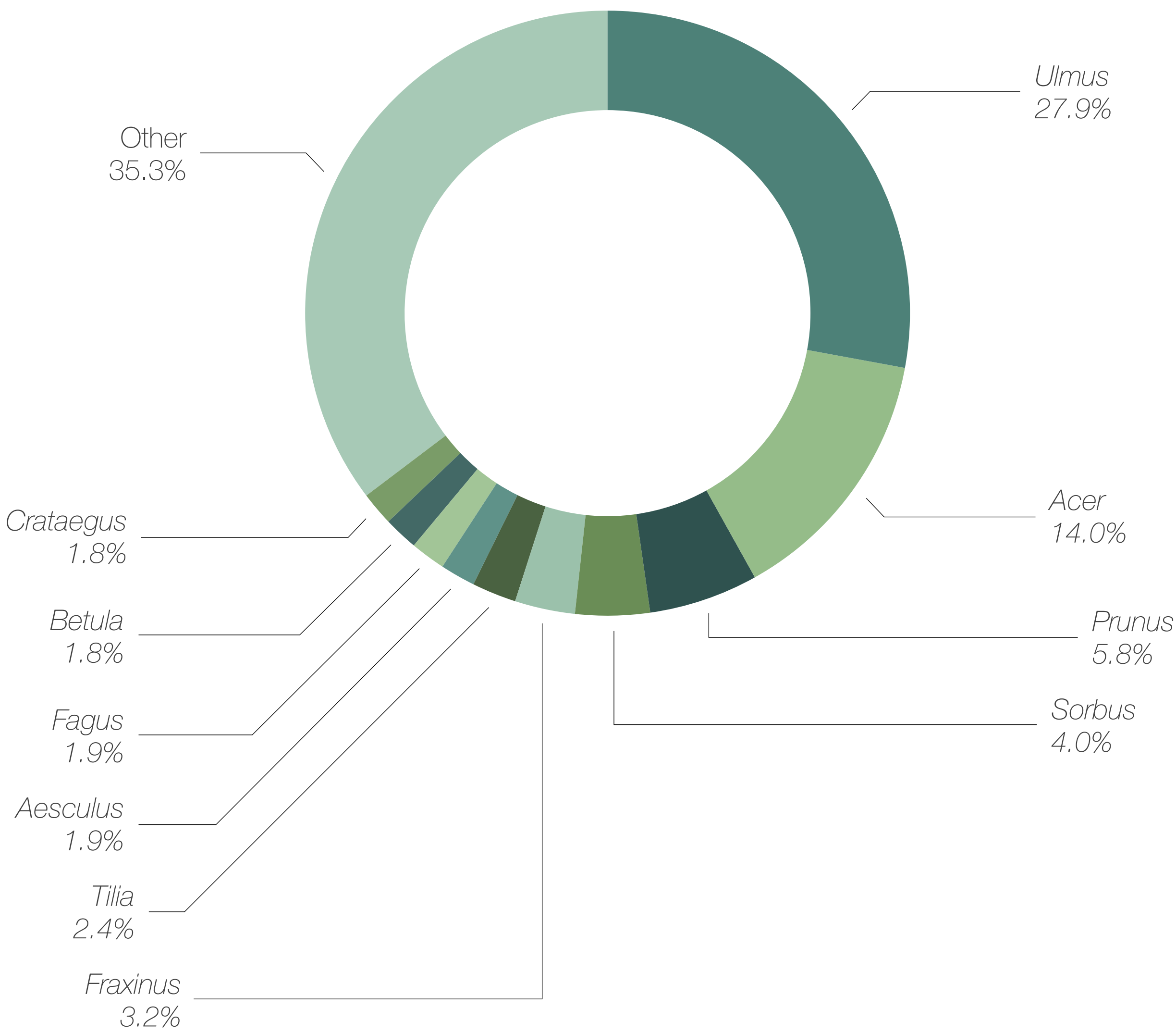

Figure 2: Tree population showing the top ten genera

2.2 Managing for Diversity

The trees of Brighton and Hove exhibit a good breadth of diversity, although the *Ulmus* is by far the most dominant. The *Ulmaceae* family, which includes *Ulmus, Celtis* and *Zelkova* makes up 28% of all trees, and dominating the canopy with 31% of leaf area (Figure 3) - a metric that is more closely aligned with ecosystem service benefits.

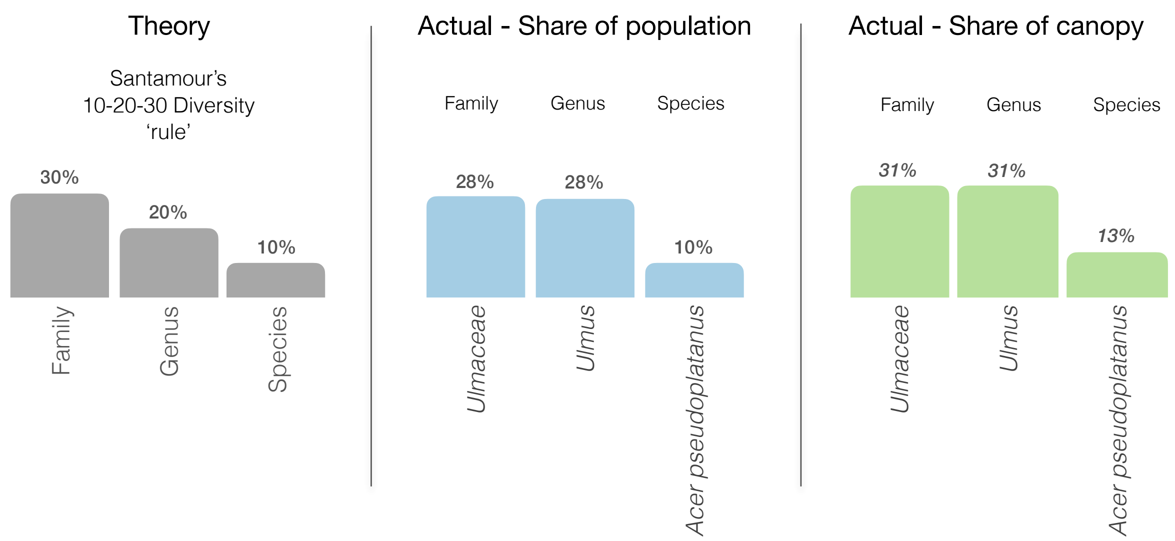

Figure 3. Benchmarking against Santamour's 10-20-30 Diversity 'rule'
Showing largest family, genus and species respectively under different metrics

Accepting this, the breadth of the species range across Brighton and Hove should enable a degree of resilience against pests and diseases although this would be higher without such a reliance on the *Ulmus* population. the most diverse city in the UK when surveyed in 2015 was London.

Setting upper limits, as suggested by Santamour[7], is a simple means to capture the diversity management challenge as it aligns well with other more sophisticated metrics - such as the Shannon[8] Diversity index - for established parks and cities[9].

Santamour's 10-20-30 rule of thumb

This suggests upper limits for a tree population as follows:

- Single species - 10%
- Single genus - 20%
- Single family - 30%

Many old city park and urban tree populations do not adhere to this rule due to historic plantings, but it can help inform future plantings.

Shannon Diversity Index

This is a single number that takes account of two key concepts in diversity:

- Richness - the number of species
- Evenness - how equally they are represented

The higher the number, the greater the diversity.

Brighton and Hove - All Trees	2.98
London Urban Forest (most diverse in UK)	3.92

[7] Santamour 1990

[8] Shannon, 1948

[9] Kendal 2014

2.3 Tree Origins

Tree diversity is an important aspect of the tree population management. Tree diversity increases overall resilience in the face of various environmental stress inducing factors, including individual diversity within (i.e. genetic diversity of seedlings) and between species of trees in terms of different genera or families (e.g. *Acer* (Maple family); *Ligustrum* (Olive family)).

A more diverse tree-scape is better able to deal with possible changes in climate or potential pest and disease impacts. Despite an over reliance on certain species, the tree population within Brighton and Hove represents a diverse community of trees given the area, with 162 species of tree identified.

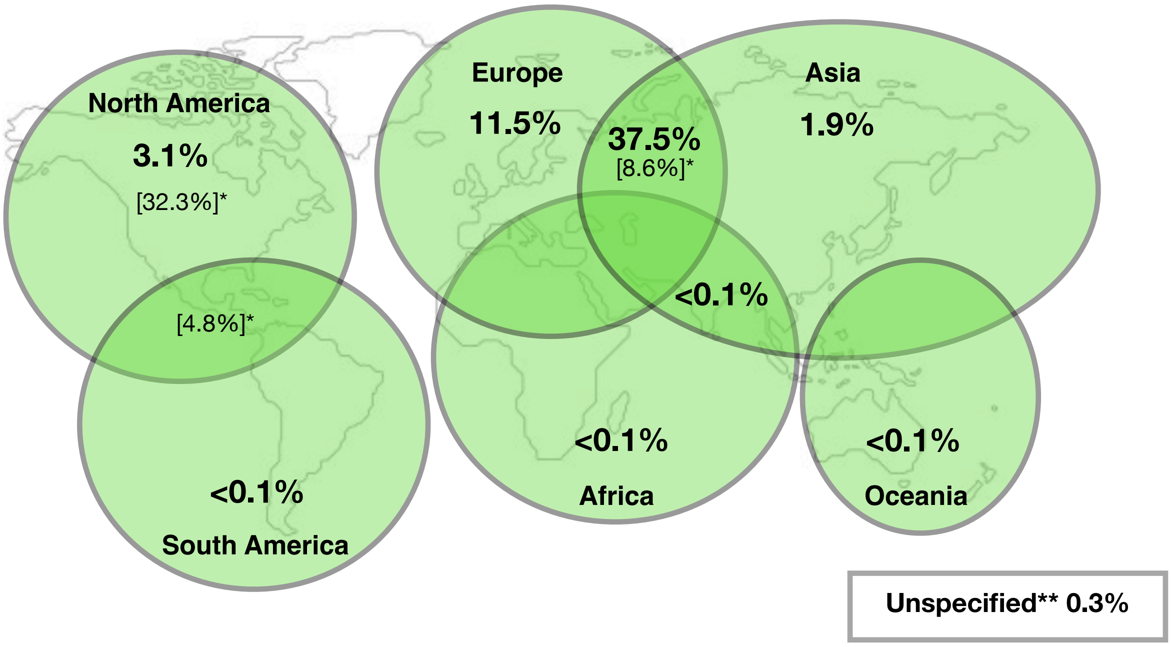

Figure 4: Origin of Tree Species
Share of trees native to different geographical regions.
Overlaps indicate origins within both continents

*In these cases, where only genus is available, the proportion in brackets may include additional regions.
**Whilst there are still a few species whose origin remains unknown, the vast bulk of this number is made up of hybrids with a likely parentage from two zones rendering the concept of regional origin mute.

2.4 Size Distribution

Size class distribution is important aspect to consider in managing a sustainable and diverse tree population, as this helps ensure that there are enough young trees to replace those older specimens that are eventually lost through old age or disease. It is also relevant in terms of benefit delivery, as generally larger trees deliver greater benefits.

In this inventory, trees are sized by their stem diameter at breast height (DBH) - approximately 1.5m. Figure 5 shows the percentage of tree population within each DBH class.

The size class distribution of trees within Brighton and Hove is well balanced in the lower size classes. However, a long term challenge is to increase the proportion of larger stature trees. High structural diversity increases the overall resilience of the tree stock.

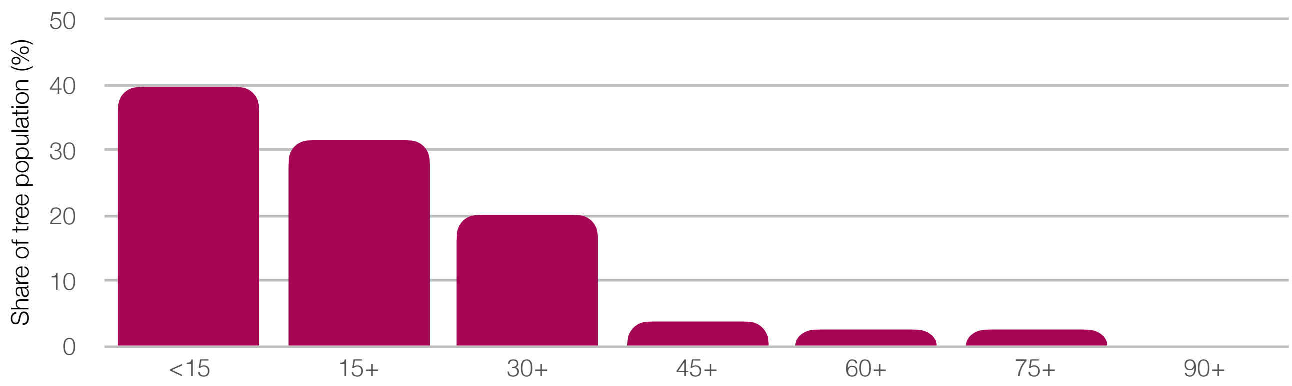

Figure 5: Tree Population by DBH Class (cm)

Where the goal is to continually maintain tree cover within a landscape, a guiding principle is an inverse J-curve of age going from many young to few mature trees[10] (Figure 6). DBH can be considered a proxy for age, bearing in mind species and potential ultimate size and form.

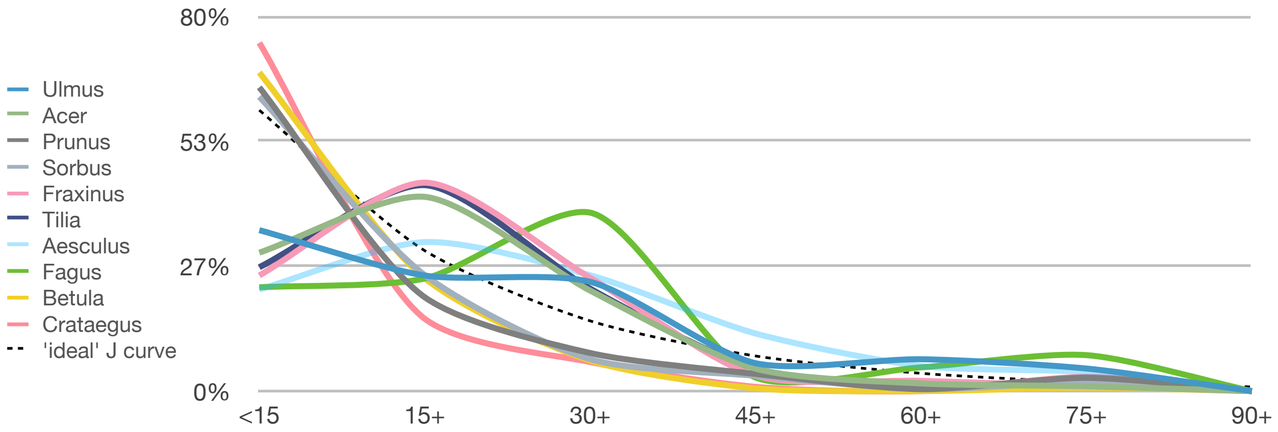

Figure 6. Spread of size classes amongst the top ten genera, showing comparison to 'ideal' J-curve'ideal'
J-curve values reduce by half for each increase in DBH class

[10]Kimmins, 2004

2.5 Leaf Area and Population

Leaf area is an important metric because the total photosynthetic area of a trees canopy is directly related to the amount of benefit provided. The larger the canopy and its surface area, the greater the amount of air pollution or stormwater which can be held in the canopy of the tree.

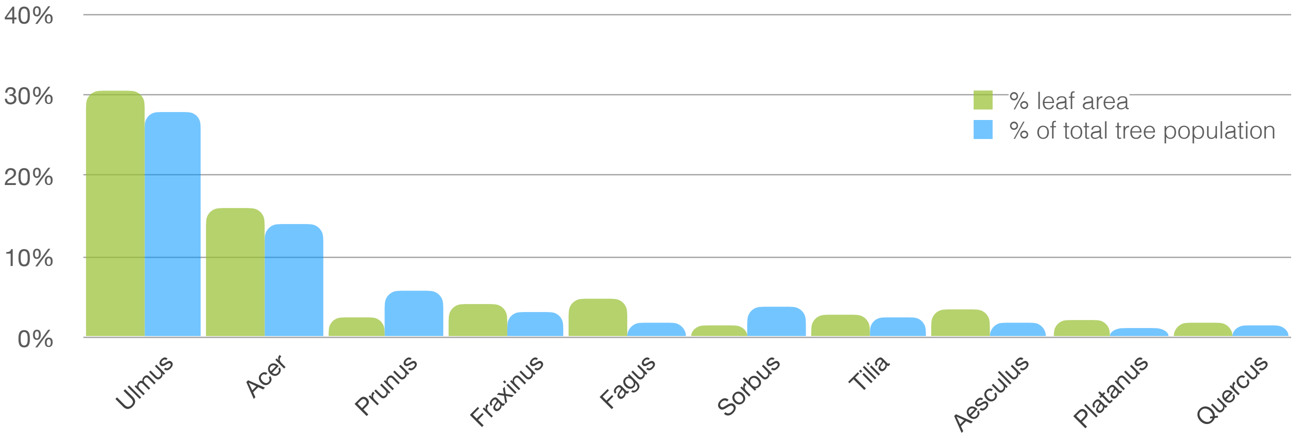

Figure 7: Share of Leaf Area vs Population for the top ten genera

Within Brighton and Hove the total leaf area is estimated at 512 ha. If all the layers of leaves within the tree canopies were spread out, they would cover an area nearly 10 times the size of Brighton Marina. The three most dominant genera in terms of leaf area are *Ulmus* (which has 30.6% of the total leaf area for all trees), *Acer* (16.1%) and *Prunus* (2.6%). Figure 7 shows the top ten dominant genera of trees' contributions to total leaf area. Representing 84.2% of the trees, these contribute almost 91.3% of the total leaf area.

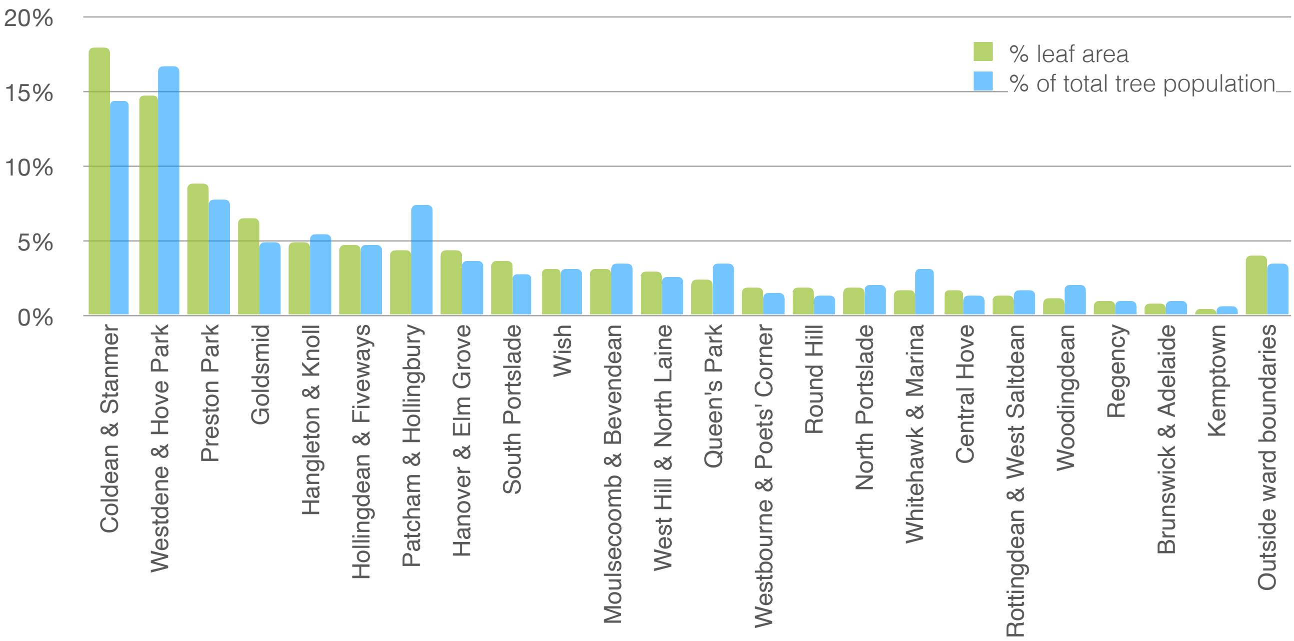

Figure 8: Share of Leaf Area vs Population by ward

When leaf area is considered on a ward by ward basis it is clear that Coldean & Stanmer dominates. In such an urban area this is understandable as Coldean & Stanmer is home to Brighton and Hove's Stanmer Park Local Nature Reserve. Coldean & Stanmer has 17.9% of the total leaf area in Brighton and Hove.

2.6 Dominance

Within the i-Tree Eco model, leaf area metrics are combined with species population data to provide a 'dominance value' for each tree species. However, a high value does not necessarily mean that these trees should be used in the future. Rather, it shows which species are currently delivering the most benefits based on their population and leaf area.

These species currently dominate the treescape within Brighton and Hove and are therefore the most important in delivering environmental benefits. The ten most dominant tree genera are shown in Figure 9. A full list of dominance values by species is given in Appendix II.

Ulmus is by far the most dominant tree in Brighton and Hove, with a dominance value of 58.4, with *Acer* and *Prunus* having values of 30.1 and 8.7 respectively in second and third most dominant.

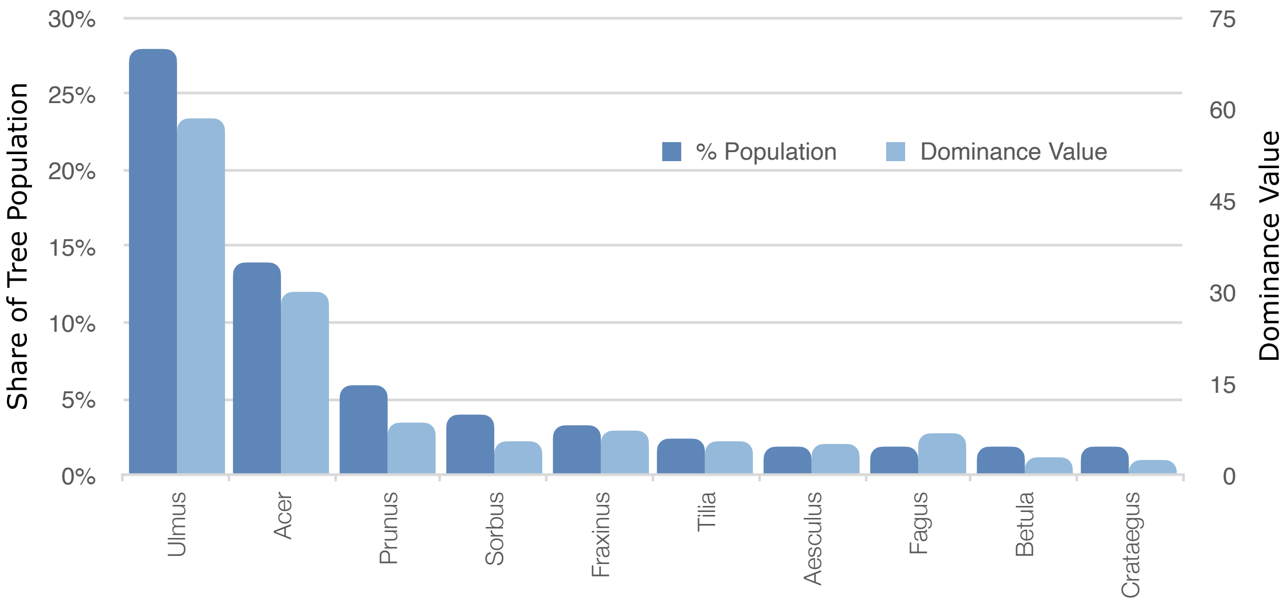

Figure 9: Dominance and population of the ten most common genera

3. Results - Ecosystem Services

3.1 Air Pollution Removal

Poor air quality is a common problem in many urban areas and along road networks. Air pollution caused by human activity has become a problem since the beginning of the industrial revolution. With the increase in population and industrialisation, large quantities of pollutants have been produced and released into the urban environment. The problems caused by poor air quality are well known, ranging from human health impacts to damage to buildings.

Urban trees can help to improve air quality by reducing air temperature and by directly removing pollutants from the air[11]. They intercept and absorb airborne pollutants through leaf surfaces[12]. In addition, by removing pollution from the atmosphere, trees reduce the risks of respiratory disease and asthma, thereby contributing to reduced health care costs[13].

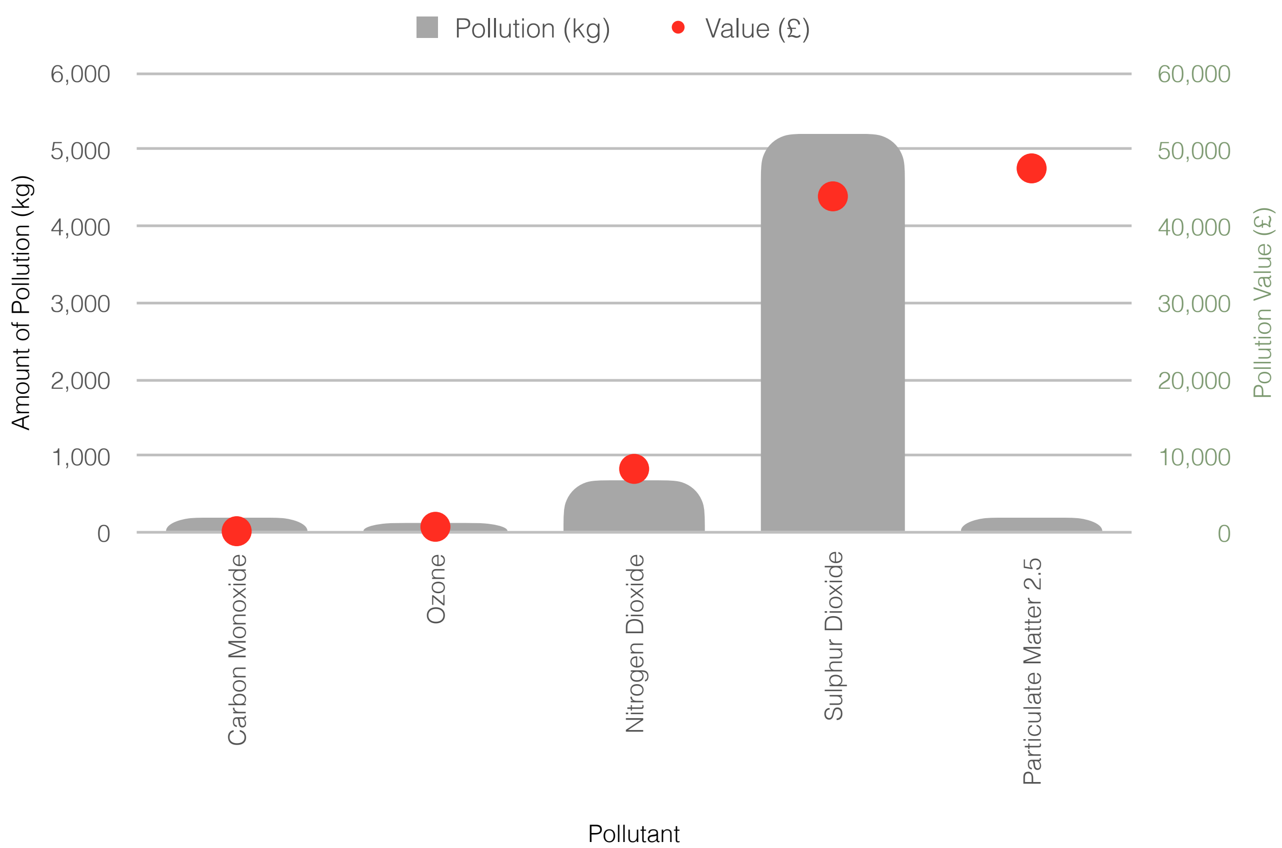

Figure 10: Value of the Pollutants Removed and Quantity Annually
Valuation method's used are UK social damage cost (UKSDC) where they are available - where there are no UK figures, the US externality cost (USEC) is used as a substitution.

[11] Tiwary et al., 2009

[12] Nowak et al., 2000

[13] Peachey et al., 2009, Lovasi et al., 2008

The situation is complicated by the fact that trees also emit volatile organic compounds (VOCs) that can contribute to low-level ozone formation; however integrated studies have revealed that an increase in tree cover leads to a general reduction in ozone through a reduction in the urban heat island effect[14].

Greater tree cover, pollution concentrations and leaf area are the main factors influencing pollution filtration and therefore increasing areas of tree planting have been shown to make further improvements to air quality. Furthermore, because filtering capacity is closely linked to leaf area it is generally the trees with larger canopy potential that provide the most benefits.

Figure 10 shows the breakdown for the top ten pollution removing tree genera in Brighton and Hove, with the species contributing the most noted in brackets. As different species can capture different sizes of particulate matter,[15] it is recommended that a broad range of species should be considered for planting in any air quality strategy.

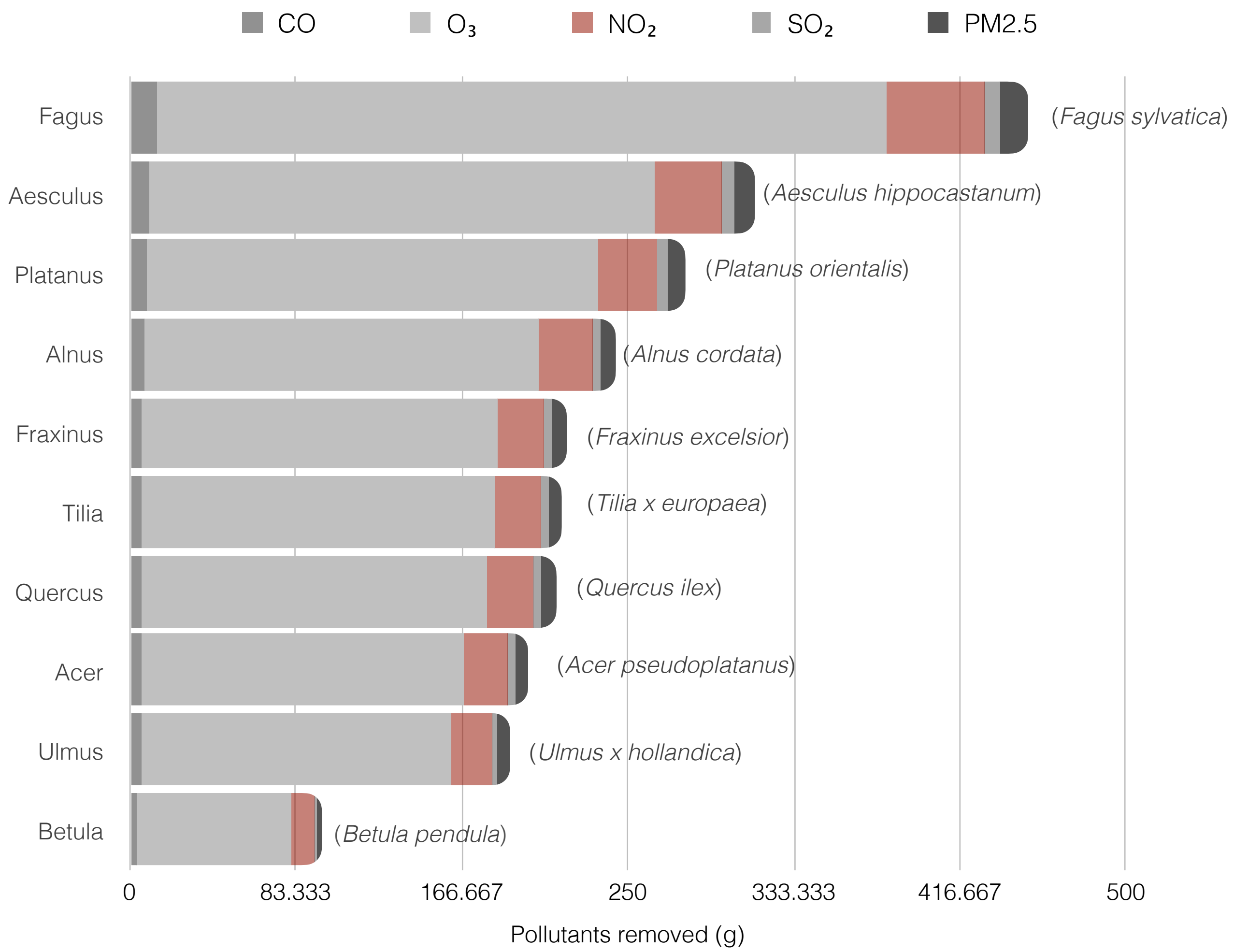

Figure 11: Top ten pollution-removing genera and their leading species on a per tree basis.
Genera only considered if totalling above 1% of inventory population (368 trees)

[14] Nowak et al.,2006

[15] Freer-Smith et al (2005)

3.2 Carbon Storage

The main driving force behind climate change is the concentration of carbon dioxide (CO_2) in the atmosphere. Trees can help mitigate climate change by storing and sequestering atmospheric carbon as part of the carbon cycle. Since about 50% of wood by dry weight is comprised of carbon, tree stems and roots can store up carbon for decades or even centuries[16].

Over the lifetime of a tree, several tons of atmospheric carbon dioxide can be absorbed[17]. Overall the trees in Brighton and Hove's inventory store 14,900 tonnes of carbon with a value of £13,600,000.

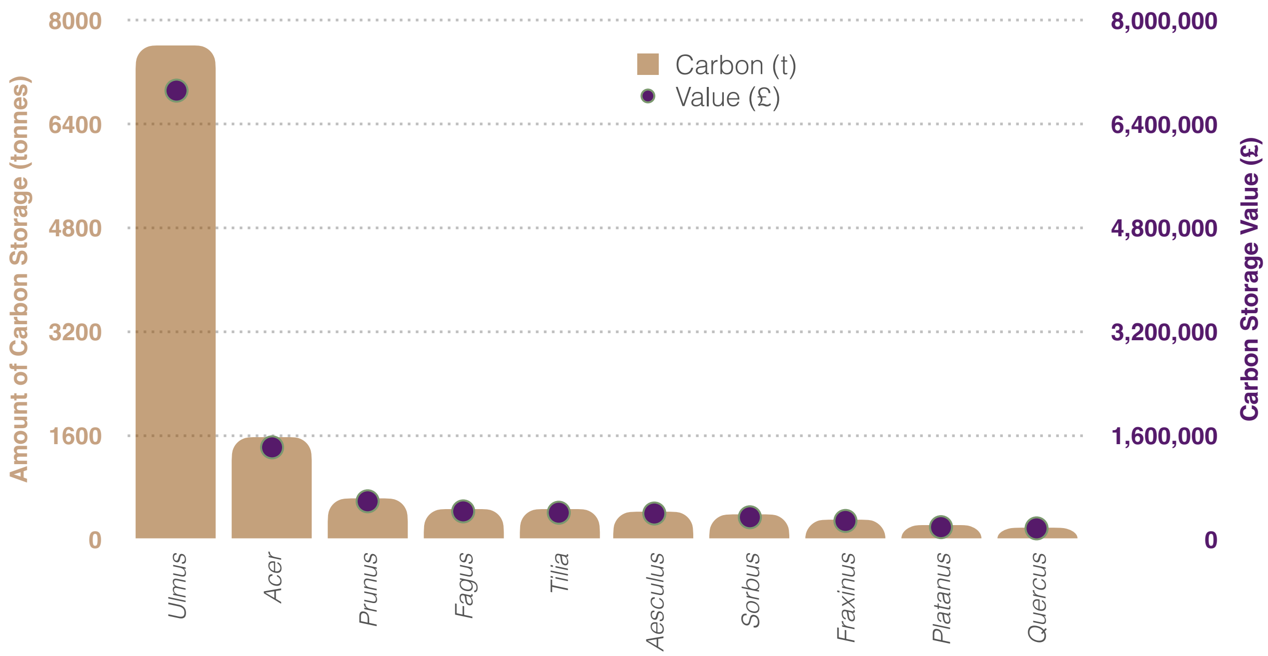

Figure 12: Carbon Storage (tonnes) and Value for top ten tree genera

As trees die and decompose they release this carbon back into the atmosphere. Therefore the carbon storage of trees and woodland is an indication of the amount of carbon that could be released if all the trees died.

Maintaining a healthy tree population will ensure that more carbon is stored than released. Utilising the timber in long term wood products or to help heat buildings or produce energy will also help to reduce carbon emissions from other sources, such as power plants.

[16] Kuhns 2008

[17] McPherson 2007

The ward with the highest carbon storage is Westdene & Hove Park (Figure 13). This should be expected with its high population of trees compared to the other wards. The exception here is Goldsmid which has significantly more trees, this highlights the importance of the age, size, health and species in affecting carbon values. Westdene & Hove Park alone contributes over £2.5 million (19.0%) of the value of stored carbon.

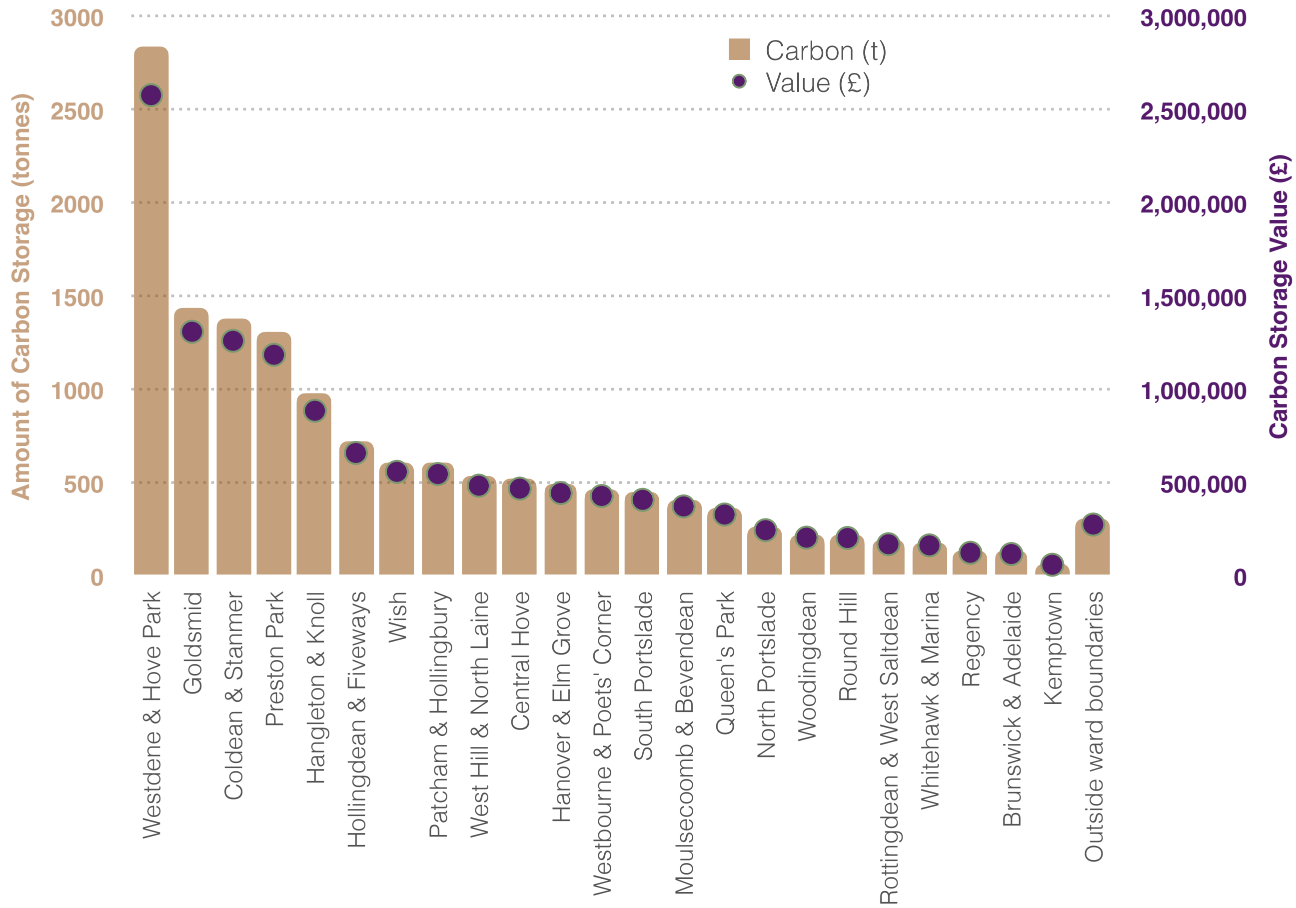

Figure 13: Carbon Storage (tonnes) and Value by Ward

3.3 Carbon Sequestration

Carbon sequestration is calculated from the predicted growth of the trees based on field measurements of the tree, climate data and species specific growth rates within Eco. This provides a volume of tree growth. This volume is then converted into tonnes of carbon based on species specific conversion factors and then multiplied by the unit cost for carbon. The current UK social cost is £248/tonne.

Brighton and Hove's inventory trees annually sequester 425 tonnes of carbon per year, with a value of £386,000. Figure 14 shows the ten tree genera that sequester the most carbon per year and the value of the benefit derived from the sequestration of this atmospheric carbon.

Of all trees inventoried, *Ulmus* sequesters the most carbon, adding 194 tonnes every year to the current *Ulmus* carbon storage of 7,590 tonnes.

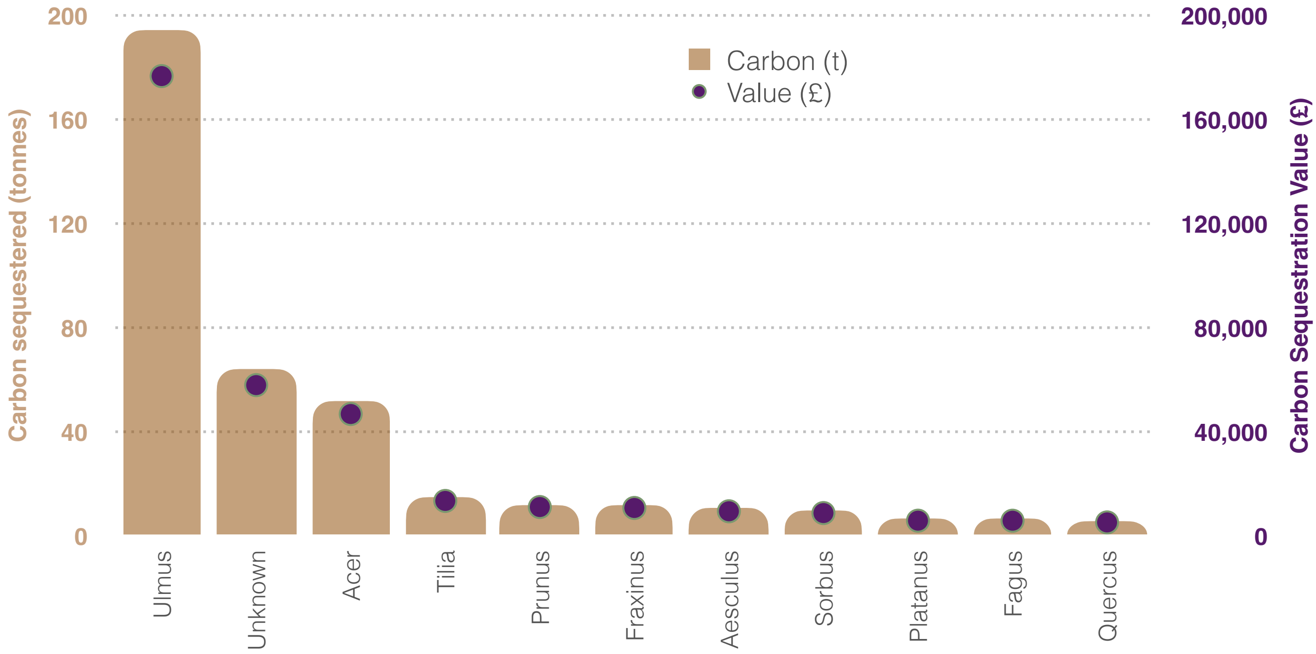

Figure 14: Carbon Sequestration (tonnes) and Value by genera

Westdene & Hove Park sequesters the most carbon, adding 67.5 tonnes annually, contributing 15.9% of the total carbon sequestration, once again this can be credited to its high population. Figure 15 shows that large green spaces such as Stanmer Nature Reserve and Wild Park Local Nature Reserve can have significant positive impact on our ecosystems and in our wider attempts to lower atmospheric carbon.

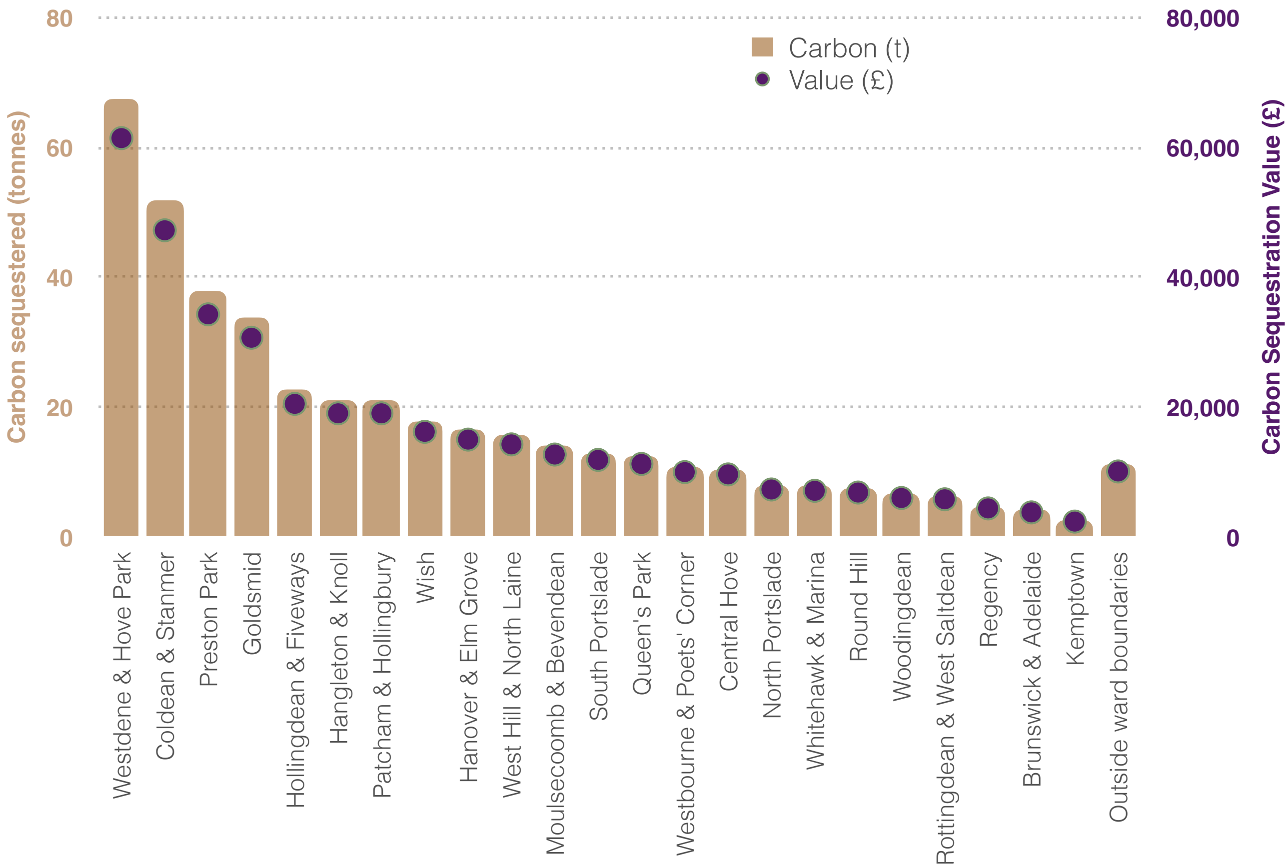

Figure 15: Carbon Sequestration and Value by ward

3.4 Avoided Run-off

Surface run-off can be a cause for concern in many areas as it can contribute to flooding and is a source of pollution in streams, wetlands, rivers, lakes, and oceans. During precipitation events, a portion of the precipitation is intercepted by vegetation (trees and shrubs) while a further portion reaches the ground. Precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff[18].

In urban areas, the large extent of impervious surfaces increases the amount of runoff. However, trees are very effective at reducing surface runoff[19]. Trees also intercept precipitation, while their root systems promote infiltration and storage in the soil.

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. The trees within Brighton and Hove help to reduce runoff by an estimated 15,300 m^3 a year with an associated value of £27,500.

Figure 16 shows the volumes and values for the ten most important genera for reducing runoff.

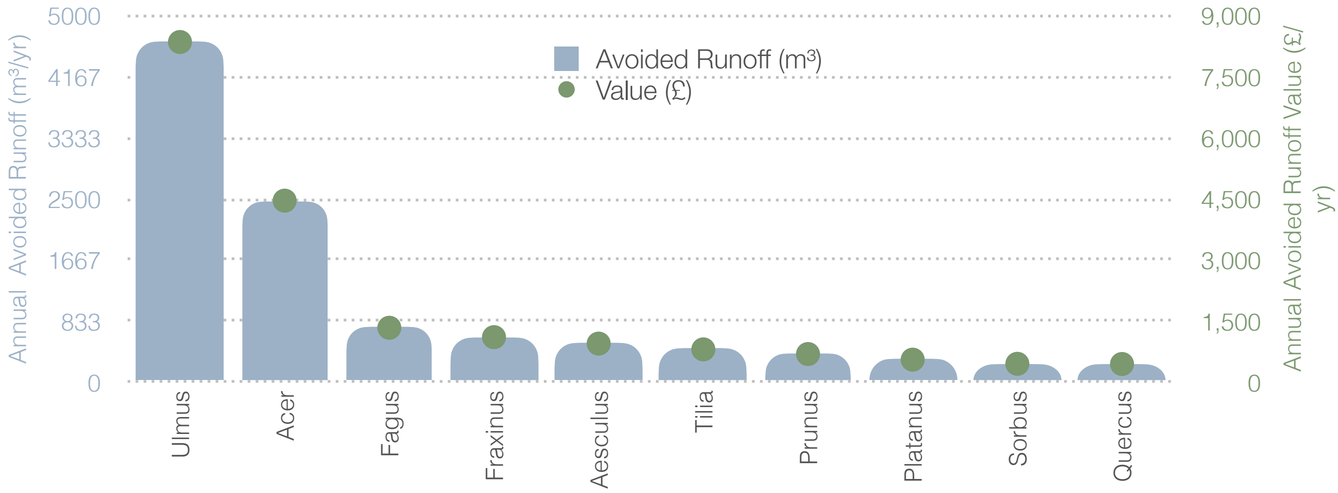

Figure 16: Avoided runoff by top ten genera

The trees in Brighton and Hove play an important role in reducing run-off: *Ulmus* accounts for 4,650 m^3 of the total precipitation intercepted, reducing runoff more than the 70 least effective genera combined. This is due to the trees population and canopy size.

15,300 m^3 is equivalent to over 6 Olympic swimming pools of stormwater being averted every single year.

[18] Hirabayashi 2012

[19] Trees in Hard Landscapes 2014

Avoided runoff calculated by ward shows Coldean & Stanmer with higher avoided runoff and associated value than the other wards in Brighton and Hove. Coldean & Stanmer stops 2,740 m^3 per year which is 17.9% of the total avoided runoff in Brighton and Hove. The second and third highest avoided runoff recorded in each ward are Westdene & Hove Park (14.6%) and Preston Park (8.9%).

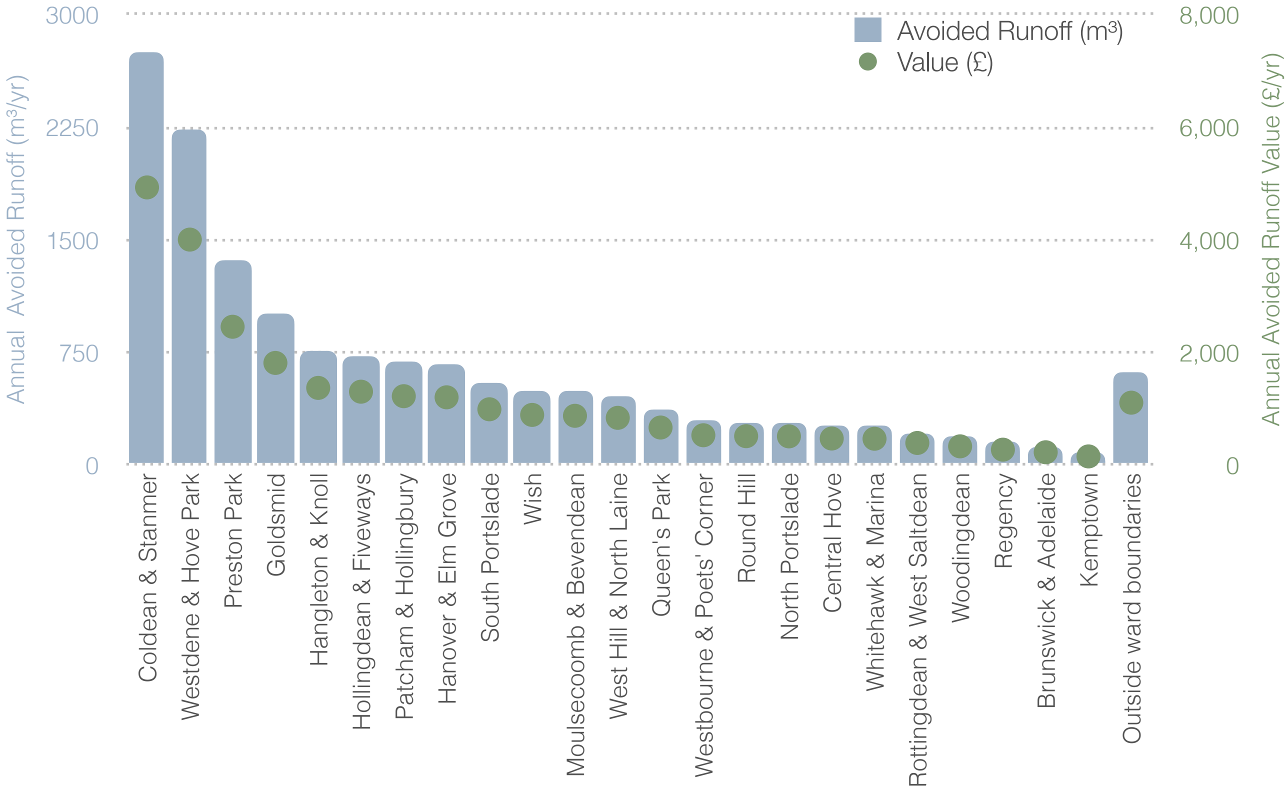

Figure 17: Avoided runoff by ward

3.5 Potential Pests and Diseases

Various insects and diseases can kill trees, reducing both their health and value, and therefore the sustainability of our urban forests. As most pests generally tend to have specific tree hosts, the potential damage that can be caused by each pest will differ.

Figure 18 shows the proportion of Brighton and Hove's trees at risk for each of the most critical invasive pests and diseases of concern to the UK according to Observatree[20], led by Forest Research.

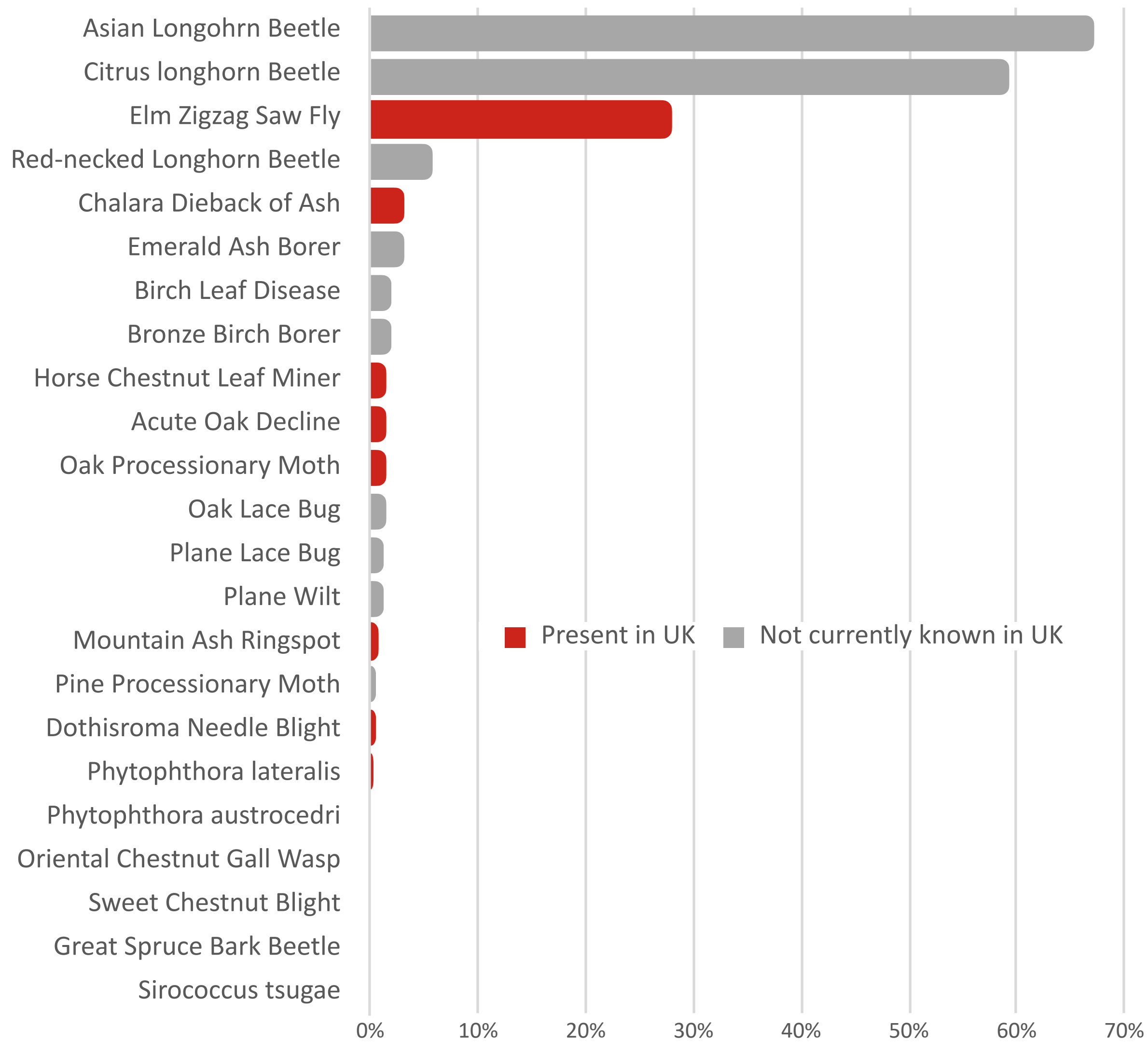

Figure 18: Share of Brighton and Hove's tree population under threat from different named pests of highest concern at time of publication (Observatree, 2022).

Potential impact varies based on climate and weather, tree health, local tree management, and individual young tree procurement policies. One long term tool for mitigating such impacts is building resilience through population diversity. Other practical steps are set out in 'Protecting Plant Health - A Plant Biosecurity Strategy for Great Britain'[21].

[20] Observatree, 2022

[21] Defra, 2014

3.6 Replacement Cost

Replacement cost is intended to provide a useful management tool, as it is able to value what it might cost to replace any or all of the trees (taking account of species suitability, depreciation and other economic considerations) should they become damaged or diseased for instance. The valuation is a depreciated replacement cost, based on the Council of Tree and Landscape Appraisers (CTLA) formulae[22]. The replacement costs for the ten most valuable tree species are shown in Figure 19 below.

The total value of all trees in the study area currently stands at £22.5 million. *Ulmus* is the most valuable genera of tree, on account of both its size and population, followed by *Acer* and *Fagus*. These three species of tree account for £11.7 million (51.9%) of the total replacement cost of the trees in Brighton and Hove. A full list of trees with the associated replacement cost is given in Appendix III

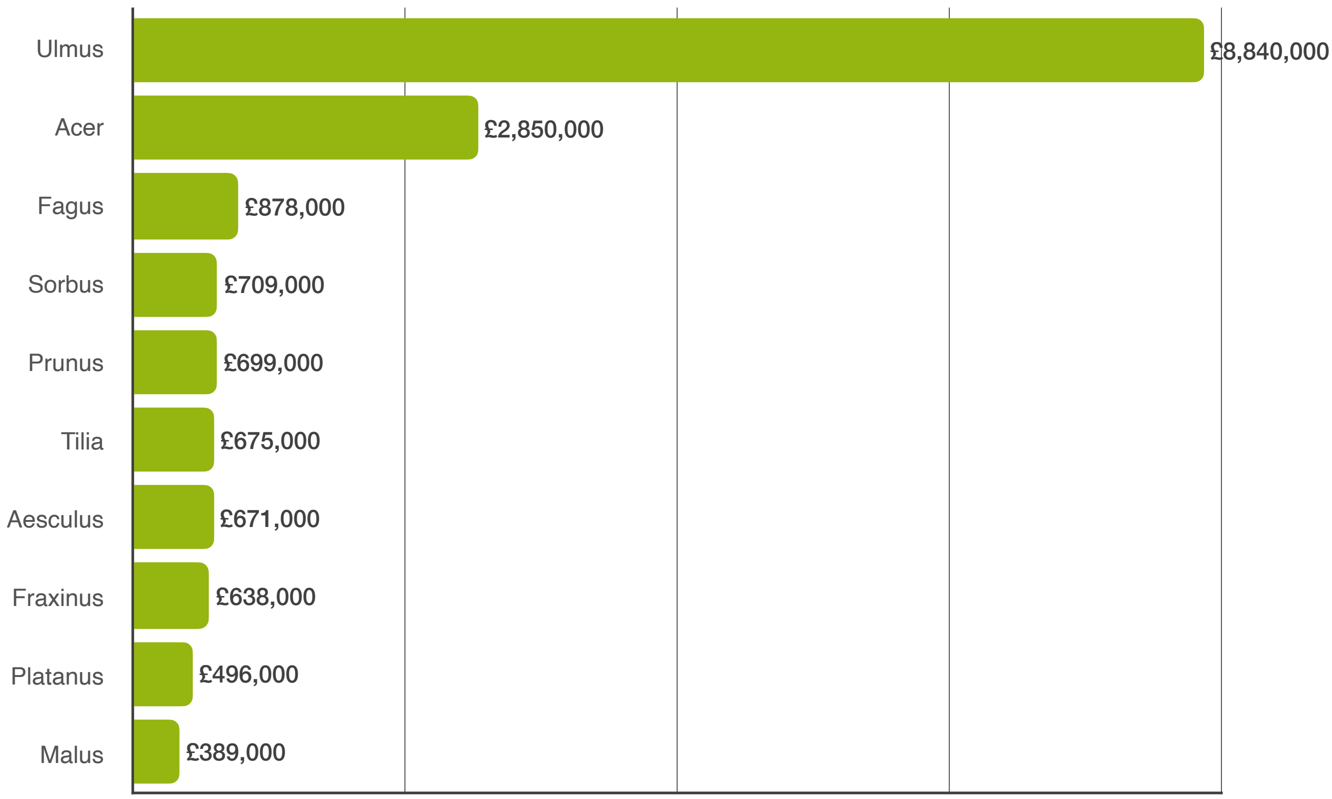

Figure 19: Replacement Cost for top ten genera

[22] Hollis, 2007

Replacement cost by ward is displayed in Figure 20. Westdene & Hove Park shows the highest replacement cost due to its high population.

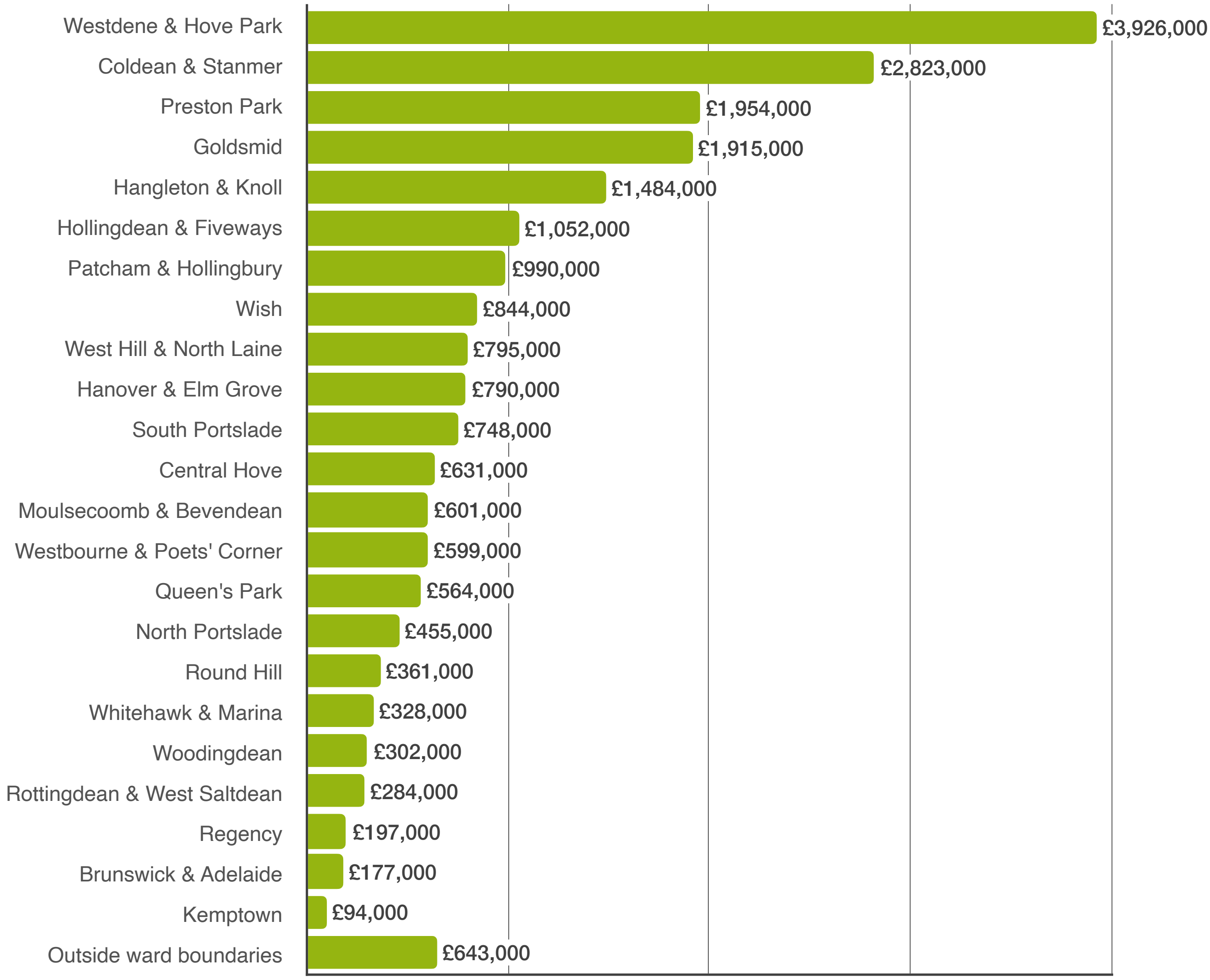

Figure 20: Replacement Cost by ward

3.7 Amenity valuation - CAVAT

Capital Asset Valuation for Amenity Trees (CAVAT) is a method developed in the UK to provide a value for the public amenity that trees provide[23]. The Council of Tree and Landscape Appraisers (CTLA) valuation method does not take into account the health or amenity value of trees, and is a management tool rather than a benefit valuation.

Particular differences to the CTLA valuation include the Community Tree Index (CTI) value, which adjusts the CAVAT assessment to take account of the greater benefits of trees in areas of higher population density, using official population figures. CAVAT allows the value of parks' trees to include a social dimension by valuing the visual accessibility and prominence within the overall urban forest.

For Brighton and Hove the estimated public amenity asset value is £549 million.

Genus	Share of Total Population	CAVAT Value
Ulmus	27.9%	£235,000,000
Acer	14.0%	£79,800,000
Unknown	20.5%	£76,000,000
Fagus	1.9%	£18,900,000
Aesculus	1.9%	£17,200,000
Prunus	5.8%	£14,300,000
Sorbus	4.0%	£14,000,000
Tilia	2.4%	£13,200,000
Platanus	1.3%	£8,990,000
Quercus	1.4%	£7,780,000
Malus	1.6%	£7,380,000
All Other Species	17.4%	£56,450,000
Total	**100%**	**£549,000,000**

Table 2: The ten genera with the highest CAVAT valuation

It should be noted that local factors do have some influence. Equally, due to the nature of street trees and the CAVAT method, management choices could not be taken into account as part of this study. The value should reflect the reality that public trees have to be managed for safety. They are often crown lifted and especially those close to the roadways are generally growing in conditions of greater stress than their open grown counterparts. As a result, they may have a significantly reduced functionality under the CAVAT system.

Ulmus exhibits the highest CAVAT valuation (Table 2), as would be expected from its dominant share of population.

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[23] Doick et al, 2016

Ward	Share of Total Population	CAVAT Value
Westdene & Hove Park	15.0%	£93,470,979
Coldean & Stanmer	13.2%	£66,361,565
Preston Park	7.9%	£49,955,607
Goldsmid	4.8%	£46,882,213
Hangleton & Knoll	5.8%	£32,394,053
Hollingdean & Fiveways	5.2%	£27,489,053
Patcham & Hollingbury	7.6%	£24,792,478
Wish	3.3%	£20,809,974
West Hill & North Laine	2.6%	£20,032,382
Hanover & Elm Grove	3.6%	£19,421,669
South Portslade	3.0%	£17,723,965
Central Hove	1.1%	£15,570,575
Moulsecoomb & Bevendean	3.5%	£15,493,095
Queen's Park	4.4%	£14,948,974
Westbourne & Poets' Corner	1.8%	£14,839,932
North Portslade	2.1%	£10,858,821
Round Hill	1.6%	£8,932,935
Whitehawk & Marina	5.4%	£7,999,482
Rottingdean & West Saltdean	1.8%	£7,806,935
Woodingdean	1.7%	£7,453,649
Regency	1.1%	£5,316,524
Brunswick & Adelaide	1.1%	£4,798,836
Kemptown	0.7%	£2,627,588
Outside ward boundaries	2.0%	£13,389,625
Total	**100%**	**£549,000,000**

Table 3: CAVAT valuation by ward

The same data shown on a ward by ward basis (Table 3) places Westdene & Hove Park at the top, perhaps unsurprisingly given it encompasses significant green spaces.

4. Brighton and Hove's Elms

This tree inventory study only takes into account the publicly owned trees in Brighton and Hove. The City is proud of its nationally important Elm collection which includes what is thought to be the largest and oldest elm in the Europe, the remaining 'Preston Twin'.

Throughout this report the genus Elm *(Ulmus)* has dominated the figures. This is understandable due to its large population in the inventory. Normally, such a dominant genera is unhealthy for an urban forest. This is because a large proportion of the trees, and the ecosystem services and social benefits they provide, are at risk from a comparatively small change. For example if Brighton and Hove were to be subject to a greater impact of Dutch Elm Disease, Elm Zig Zag Saw Fly or an environmental change that restricted the Elm's ideal growing conditions the overall tree population would suffer disproportionately. This is an illustration of high dominance lowering resilience throughout the urban forest.

The introduction of Dutch Elm Disease in the UK has meant the devastation of Elm populations throughout the UK. The meticulous management of infected trees in East Sussex has proven successful. As a result there are now more Elms in this part of the country than before the introduction of Dutch Elm Disease in the late 1960s.[24]

In this case, resilience being lowered by the high number of Elms is mitigated partially by the fact that there is high diversity within the Elm collection. Brighton and Hove have at least 6 major species and approximately 30 cultivars of Elm recorded in this study. Intra-species diversity is often the saving grace of dominant populations, Where many cities see a dominant genera with only one or two species, Brighton's dedication to the management of Elms has resulted in an increasingly rare healthy Elm population.

As demonstrated throughout this study this Elm population provides a large amount of ecosystem services to Brighton and Hove which is only possible due to its diversity and health.

Tree Inventory - Headline Figures	
Total Number of Elms Measured	10,268
Most Common Species	*Ulmus hollandica, Ulmus minor, Ulmus procera*
Replacement Cost	£8.8 million
CAVAT Valuation	£235 million
Species Recorded	6

Table 4: Elm Headline Figures

Amounts and Values		
Carbon Storage	7,590 tonnes	£6.9 million
Pollution Removal	1.9 tonnes/yr	£30,800
Carbon Sequestration	194 tonnes/yr	£177,000
Avoided Runoff	4,650 m³/yr	£8,350
Total Annual Benefits	**£216,150**	

Table 5: Elm Amounts and Values

[24] Woodland Trust, 2022

4. Conclusions

The tree population within Brighton and Hove generally has a good species and age diversity. This will provide some resilience from possible future influences such as climate change and pest and disease outbreaks. The role of Brighton and Hove's trees in complementing people's health is clear. Brighton and Hove's trees provide a valuable public benefit - at least £514,500 in environmental services each year.

In terms of structural diversity all tree species are well represented. Brighton and Hove benefits by having a wide variety of species within a broad range of DBH classes. However, an over reliance on *Ulmus* may become a concern as it makes the tree population more vulnerable to pests, diseases and future environmental changes (The top 3 population of genera represents 27.9%, 14% and 5.8% respectively). Diversity in both species and size benefits a location like Brighton and Hove by offering resilience within the tree population and continued ecosystem services should ageing stock require removal.

Furthermore, the values presented in this study represent only a portion of the total value of the trees within Brighton and Hove because only a proportion of the total benefits have been evaluated. Trees confer many other benefits, such as contributions to our health and well being that cannot yet be quantified and valued. Therefore, the values presented in this report should be seen as conservative estimates.

The extent of these benefits needs to be recognised, and strategies and policies that will serve to conserve this important resource (through education for example) would be one way to address this.

As the amount of healthy leaf area equates directly to the provision of benefits, future management of the tree stock is important to ensure canopy cover levels continue to be maintained or increased. This may be achieved via new planting, but the most effective strategy for increasing average tree size and the extent of tree canopy is to preserve and adopt a management approach that enables the existing trees to develop a stable, healthy, age and species diverse, multi-layered population.

Climate change could affect the tree stock in Brighton and Hove in a variety of ways and there are great uncertainties about how this may manifest. Further study into this area would be useful in informing any long term tree and parkland strategies, such as species choice for example.

The challenge now is to ensure that policy makers and practitioners take full account of Brighton and Hove's trees in decision making. Not only are trees a valuable functional component of our landscape they also make a significant contribution to peoples quality of life.

A follow-up report considering how Brighton and Hove's trees could be fully considered in the Brighton and Hove City Council's decision making and a sustainable urban forest masterplan is recommended.

5. Recommendations

The results and data from previous i-Tree Eco studies have been used in a variety of ways to improve the management of trees and inform decision making. The information in this report on the structure, composition and value of The Inventory can be used to make more informed decisions on how these trees can be managed to provide long-term benefits to communities. This is one of the key outcomes of undertaking a project such as this.

Use the approach and findings to inform the development of Brighton and Hove's other strategies.

Data can be used to inform species selection for increased tree diversity thereby lessening the impacts from potential threats like plane wilt.

Use report data to produce educational information about The Inventory's trees (e.g. informational tree tags).

Use the data for cost benefit analysis to inform decision making.

Undertake a gap analysis to help inform where to plant trees to optimise ecosystem services and maximise the benefits, to align with the objectives and priorities of Brighton and Hove's tree management plan.

Inform species selection. Size does matter! Identify trees that can grow to full maturity and reach their optimal canopy size (given any site specific restrictions) and contribute the most benefits to the surrounding urban communities. Review together with an ancient tree management plan to include non-natives and heritage trees to broaden the potential for the inventory trees to build resilience to future change.

Use the report and data to produce educational and public information about Brighton and Hove's trees.

Use the findings from this report to put together a business case for research into tree diversity with RBG Kew and Treeconomics

Appendices

Appendix I. Relative Tree Effects

The trees in Brighton and Hove provide benefits that include carbon storage and sequestration and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average carbon emissions and average family car emissions. These figures should be treated as a guideline only as they are largely based on US values (see footnotes).

Carbon storage is equivalent to:

- Annual carbon (C) emissions from 11,600 family cars
- Annual C emissions from 4,770 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 6 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 110 family cars
- Annual nitrogen dioxide emissions from 49 single-family houses

Sulphur dioxide removal is equivalent to:

- Annual sulphur dioxide emissions from 1,310 family cars
- Annual sulphur dioxide emissions from 3 single-family houses

Carbon sequestration is equivalent to:

- Annual carbon (C) emissions from 300 family cars
- Annual C emissions from 100 single-family houses

Average passenger automobile emissions per mile were based on dividing total 2002 pollutant emissions from light-duty gas vehicles (National Emission Trends http://www.epa.gov/ttn/chief/trends/index.html) divided by total miles driven in 2002 by passenger cars (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/).

Average annual passenger automobile emissions per vehicle were based on dividing total 2002 pollutant emissions from light-duty gas vehicles by total number of passenger cars in 2002 (National Transportation Statistics http://www.bts.gov/publications/national_transportation_statistics/2004/).

Carbon dioxide emissions from automobile assumed six pounds of carbon per gallon of gasoline if energy costs of refinement and transportation are included (Graham, R.L., Wright, L.L., and Turhollow, A.F. 1992. The potential for short-rotation woody crops to reduce U.S. CO2 Emissions. Climatic Change 22:223-238).

Appendix II. Species Importance Ranking List

Species	Percent Population	Percent Leaf Area	Importance Value
Ulmus	27.9	30.6	58.5
Acer	14.0	16.1	30.1
Prunus	5.8	2.6	8.5
Fraxinus	3.2	4.1	7.3
Fagus	1.9	4.9	6.7
Sorbus	4.0	1.6	5.6
Tilia	2.4	3.0	5.3
Aesculus	1.9	3.4	5.2
Platanus	1.3	2.0	3.3
Quercus	1.4	1.7	3.1
Betula	1.8	1.0	2.9
Alnus	1.2	1.6	2.8
Crataegus	1.8	0.6	2.4
Malus	1.6	0.6	2.2
Ilex	1.1	0.4	1.5
Hesperotropsis	0.7	0.6	1.3
Cupressus	0.6	0.4	1.0
Taxus	0.7	0.3	1.0
Pyrus	0.7	0.3	1.0
Populus	0.4	0.5	0.8
Pinus	0.5	0.3	0.8
Corylus	0.6	0.2	0.8
Sambucus	0.7	0.1	0.7
Carpinus	0.5	0.3	0.7
Robinia	0.3	0.2	0.5
Salix	0.2	0.2	0.4
Chamaecyparis	0.2	0.2	0.4
Juglans	0.2	0.1	0.3
Cercis	0.2	<0.1	0.3
Ginkgo	0.2	<0.1	0.3
Castanea	0.1	0.1	0.2

Species	Percent Population	Percent Leaf Area	Importance Value
Ligustrum	0.2	0.1	0.2
Laburnum	0.1	<0.1	0.2
Zelkova	0.1	0.1	0.2
Liriodendron	0.1	0.1	0.2
Ostrya	0.1	<0.1	0.1
Cedrus	0.1	<0.1	0.1
Thuja	0.1	0.1	0.1
Laurus	0.1	<0.1	0.1
Celtis	<0.1	<0.1	0.1
Eucalyptus	<0.1	0.1	0.1
Paulownia	0.1	<0.1	0.1
Catalpa	<0.1	<0.1	0.1
Picea	<0.1	<0.1	0.1
Liquidambar	0.1	<0.1	0.1
Ailanthus	<0.1	<0.1	0.1
Metasequoia	<0.1	<0.1	0.1
Olea	0.1	<0.1	0.1
Rhus	<0.1	<0.1	0.0
Sophora	<0.1	<0.1	0.0
Larix	<0.1	<0.1	0.0
Sequoiadendron	<0.1	<0.1	0.0
Magnolia	<0.1	<0.1	0.0
Tamarix	<0.1	<0.1	0.0
Arbutus	<0.1	<0.1	0.0
Cercidiphyllum	<0.1	<0.1	0.0
Buddleja	<0.1	<0.1	0.0
Koelreuteria	<0.1	<0.1	0.0
Parrotia	<0.1	<0.1	0.0
Hippophae	<0.1	<0.1	0.0
Cordyline	<0.1	<0.1	0.0
Mespilus	<0.1	<0.1	0.0
Davidia	<0.1	<0.1	0.0
Elaeagnus	<0.1	<0.1	0.0

Species	Percent Population	Percent Leaf Area	Importance Value
Morus	<0.1	<0.1	0.0
Pterocarya	<0.1	<0.1	0.0
Iva	<0.1	<0.1	0.0
Gleditsia	<0.1	<0.1	0.0
Cornus	<0.1	<0.1	0.0
Name Unspecified	20.5	21.5	42.0

Appendix III. Tree Values by Species

Species	Trees	Carbon Storage (Tonnes)	Gross Carbon Seq (Tonnes/Yr)	Avoided Runoff (m^3/Yr)	Pollution Removal (Tonne/Yr)	Replace-ment Cost (£)
Ulmus	10,268	7,594.7	194.3	4650.0	1.96	£8,844,324
Acer	5153	1,551.3	51.4	2482.4	1.03	£2,853,338
Prunus	2150	637.6	12.1	386.3	0.17	£698,857
Sorbus	1465	366.7	9.5	252.9	0.10	£708,597
Fraxinus	1186	304.6	11.7	617.1	0.26	£638,108
Tilia	873	444.3	14.7	450.1	0.19	£674,636
Aesculus	691	430.5	10.3	529.0	0.22	£671,289
Fagus	690	466.7	6.3	745.5	0.31	£877,716
Betula	676	101.4	5.5	148.6	0.07	£143,973
Crataegus	660	133.2	2.2	96.1	0.04	£233,725
Malus	578	168.7	2.5	92.5	0.04	£389,144
Quercus	506	178.6	5.6	250.3	0.11	£374,730
Platanus	466	199.4	6.3	309.6	0.13	£496,315
Alnus	425	75.6	2.7	245.8	0.10	£382,397
Ilex	407	44.5	1.2	64.7	0.02	£132,871
Hesperotropsis	263	114.9	5.3	95.5	0.04	£111,261
Pyrus	261	36.5	1.4	43.9	0.02	£94,036
Taxus	244	46.7	1.2	53.4	0.02	£125,705
Sambucus	244	17.4	0.7	2.8	<0.01	£31,385
Cupressus	227	131.5	3.3	64.4	0.03	£140,876
Corylus	216	17.1	1.1	25.6	0.01	£30,937
Pinus	171	34.8	1.2	53.0	0.02	£86,838
Carpinus	171	24.1	1.0	39.2	0.02	£48,182
Populus	133	112.8	3.4	74.9	0.03	£59,131
Robinia	111	20.6	1.0	34.7	0.01	£36,649
Salix	92	39.6	1.2	23.9	0.01	£53,486
Cercis	87	1.7	0.2	3.0	<0.01	£5,735
Chamaecyparis	84	16.7	0.5	23.7	0.01	£39,377
Ginkgo	80	1.6	0.1	5.7	<0.01	£10,871
Ligustrum	66	6.8	0.3	7.3	<0.01	£13,179
Juglans	64	7.7	0.3	18.2	0.01	£24,668

Species	Trees	Carbon Storage (Tonnes)	Gross Carbon Seq (Tonnes/Yr)	Avoided Runoff (m^3/Yr)	Pollution Removal (Tonne/Yr)	Replace-ment Cost (£)
Laburnum	50	13.4	0.2	6.3	<0.01	£19,714
Castanea	46	8.5	0.3	18.2	0.01	£31,576
Ostrya	43	2.0	0.2	5.6	<0.01	£4,012
Liriodendron	37	5.3	0.2	8.6	<0.01	£14,854
Laurus	28	6.3	0.2	4.3	<0.01	£6,520
Cedrus	25	12.8	0.4	6.9	<0.01	£13,088
Zelkova	25	4.6	0.1	15.9	0.01	£22,364
Thuja	22	1.4	<0.1	8.6	<0.01	£12,500
Liquidambar	20	0.5	<0.1	1.0	<0.01	£2,353
Paulownia	20	0.7	<0.1	2.2	<0.01	£4,951
Olea	19	0.3	<0.1	0.3	<0.01	£788
Celtis	18	0.5	<0.1	4.0	<0.01	£6,555
Metasequoia	15	0.6	<0.1	2.4	<0.01	£3,109
Rhus	15	0.6	<0.1	1.0	<0.01	£2,771
Picea	14	2.7	0.1	3.8	<0.01	£5,303
Catalpa	14	1.0	0.1	4.2	<0.01	£4,649
Sophora	13	2.0	0.1	1.9	<0.01	£3,820
Ailanthus	11	5.2	0.2	4.4	<0.01	£10,617
Sequoiadendron	11	4.5	0.1	2.0	<0.01	£5,293
Eucalyptus	10	1.7	0.1	7.6	<0.01	£9,094
Tamarix	10	0.1	<0.1	<0.1	<0.01	£390
Arbutus	9	0.3	<0.1	0.5	<0.01	£617
Larix	9	1.5	<0.1	3.6	<0.01	£2,727
Magnolia	8	0.7	<0.1	1.3	<0.01	£1,607
Cercidiphyllum	6	0.2	<0.1	1.3	<0.01	£1,219
Buddleja	6	0.4	<0.1	0.5	<0.01	£952
Davidia	5	<0.1	<0.1	<0.1	<0.01	£195
Mespilus	5	0.1	<0.1	0.1	<0.01	£185
Hippophae	5	0.7	<0.1	0.5	<0.01	£976
Koelreuteria	5	0.6	<0.1	0.8	<0.01	£772
Cordyline	5	0.2	<0.1	<0.1	<0.01	£1,864
Parrotia	4	0.5	<0.1	1.2	<0.01	£1,089

Species	Trees	Carbon Storage (Tonnes)	Gross Carbon Seq (Tonnes/Yr)	Avoided Runoff (m^3/Yr)	Pollution Removal (Tonne/Yr)	Replace -ment Cost (£)
Elaeagnus	4	0.2	<0.1	0.3	<0.01	£205
Morus	3	0.2	<0.1	0.5	<0.01	£626
Gleditsia	3	<0.1	<0.1	0.1	<0.01	£143
Hedera	2	<0.1	<0.1	<0.1	<0.01	£73
Cornus	2	0.2	<0.1	0.3	<0.01	£504
Pterocarya	2	0.4	<0.1	0.8	<0.01	£945
Iva	2	0.5	<0.1	0.6	<0.01	£954
Araucaria	1	<0.1	<0.1	0.1	<0.01	£93
Carya	1	<0.1	<0.1	<0.1	<0.01	£39
Pittosporum	1	0.4	<0.1	0.3	<0.01	£519
Name Unspecified	7543	1,500.8	63.6	3281.2	1.38	£3,310,412
Total	**36,805**	**14911.0**	**424.8**	**15293.3**	**6.42**	**£22,543,375**

Appendix IV. Notes on Methodology

iTree

i-Tree Eco is designed to use standardised field data from randomly located plots and local hourly air pollution and meteorological data to quantify forest structure and its numerous effects, including:

- Forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by trees, and its associated percent air quality improvement throughout a year. Pollution removal is calculated for ozone, sulphur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (<2.5 microns).
- Total carbon stored and net carbon annually sequestered by trees.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power plants.
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian Longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations[25]. To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x+1.

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of trees account for decomposition[26].

Recent updates (2011) to air quality modelling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulphur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models[27]. As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal

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[25] Nowak 1994

[26] Nowak, David J., Hoehn, R., and Crane, D. 2007.

[27] Baldocchi 1987, 1988

rates (deposition velocities) for these pollutants were based on average measured values from the literature[28] [29] that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere[30].Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis. The value of avoided runoff is based on estimated or user-defined local values. As the local values include the cost of treating the water as part of a combined sewage system the lower, national average externality value for the United States is utilised and converted to local currency with user-defined exchange rates.

Replacement Costs were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition and location information[31] [32].

For a full review of the model see UFORE (2010) and Nowak and Crane (2000).
For UK implementation see Rogers et al (2014).
Full citation details are located in the bibliography section

[28] Bidwell and Fraser 1972

[29] Lovett 1994

[30] Zinke 1967

[31] Hollis, 2007

[32] Rogers et al (2012)

Data Formatting

The Tables below show the list of edits which were made for this project in order to enable the street tree inventory to be processed. In total 36,805 records were processed using i-Tree Eco. If the condition of the tree was unknown then a 'fair' (82%) condition was applied.

Reason for Removal	Details	Number of records removed
No Tree	Invalid location data	280
	Stump / space / no tree etc.	759
	Dead	912
No DBH or Height		5,314
TOTAL RECORDS REMOVED		**7,265**

Table 5: Inventory Records removed for use in Eco

Incomplete data	Supplied data	Assumed data for I-Tree	
Records supplied with multiple trees within a single record. iTree required each tree to be considered individually	762 records containing 2 to 1000 trees each	14,602 individual records were created with one for each tree. It assumed that all trees had the same DBH, Height and crown spread as for the original record	
Records supplied containing more than one species, class only, or unknown. Species assigned based on inferred split where named or in line with overall population spread for larger sets. Percentages based on National Forestry Index species mix (this has been proportionally upscaled to account for 'other' species)	Generic / Broadleaf	*Quercus robur*	*21%*
		Betula pendula	*21%*
		Fraxinus excelsior	*13%*
		Acer pseudoplatanus	*10%*
		Fagus sylvatica	*9%*
		Corylus avellana	*8%*
		Crataegus monogyna	*6%*
		Alnus glutinosa	*5%*
		Salix spp.	*5%*
		Castanea sativa	*2%*
	Conifer	*Pinus sylvestris*	*80%*
		Picea sitchensis	*15%*
		Pseudotsuga menziesii	*3%*
		Tsuga heterophylla	*3%*

Table 6: Assignment of species within records containing multiple species, class only or unknown

Data	Assumption
Accessibility	All trees are treated as having 100% accessibility in line with standard CAVAT assumptions for street trees and parks.
Safe Life Expectancy	Factor of 95% applied for all species (40-80 years) except *Fraxinus* species (30%) and *Prunus* species (55%)
Community Tree Index	Reference level for Brighton and Hove applied of 125%
Amenity Value (Species, Habitat, Setting, Heritage)	Assumed no uplift and no reduction on any parameter

Table 7: CAVAT Assumptions

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